found in those high schools and colleges that pursue the course of study laid out in Davis' Elementary Meteorology; but for the lower grades of public schools a teacher who has at hand the text-books by Waldo, Davis, Russell, or any other of the numerous recent authors, will prefer to mark out a course of observation and study that requires no text-book in the hands of the scholar, except his own daily record and the daily map of the Weather Bureau. In this case the scholar looks to the teacher entirely for his mental stimulus, the teaching is done entirely by personal observations and verbal discussions; the teacher, as it were, pries into the scholar's thoughts, finds out the errors that he is liable to make, and helps him to discover the truth for himself. He does not cram the scholar, but leads him to think for himself and find his own way out of the woods. This process is infinitely superior to the ordinary text-book method, but, of course, it implies very careful leadership on the part of the teacher.

To schools that adopt this method of teaching the circular that has just been sent out by a committee at Cambridge, Mass., will come as a welcome stimulus. The schools that can show the best work done, or the best record of work done in the study of weather and climate, will doubtless be proud to carry off the prize offered by the committee, whose circular reads as follows:

PRIZES FOR SCHOOL WORK ON WEATHER AND CLIMATE.

On the dissolution of the New England Meteorological Society, in 1896, a sum of about $100 was left in the hands of the undersigned committee to be used "for some meteorological purpose." In order to carry out the wishes of the society the committee offers three annual prizes of $12, $10, and $8 for the best work on weather and climate in any New England public school below the high school, according to conditions stated below. The prizes will be awarded to the school, not to the scholars. It is hoped that the fund will be enlarged by subscription, so that the prizes may be continued for a number of years.

The prizes will be awarded by judges to be selected at a later date. Each competing school may submit the work of three pupils selected by the teacher from the work of a single class.

All papers and record books sent are to be wholly the work of the pupils whose names they bear; all records are to be the result of the pupils' own observation; the papers received will be taken to represent the best products of work done by an entire class, that is, all members of the class are to do work similar to that of the three pupils whose papers are forwarded to the committee.

With the work of each pupil a paper should be sent stating (1) name of pupil; (2) age, in years and months; (3) name of school and grade or class (counting first year in school as first grade, second year, second grade, etc.); (4) name of teacher; (5) town or city, and State.

The committee does not desire to limit the work closely or to require uniformity. The work may be done as special study in weather and climate, or it may be part of a course in nature study or in geography. But the committee suggests the following topics as appropriate:

(1) Observation and record of simple weather elements.

(2) Preparation of weather maps based on data supplied by the teacher.

(3) The use of weather maps and of local observations in simple weather predictions.

(4) Special observation and study of the elements that control the climate of New England.

The judges will make due allowance for the age of pupils and their school grade, and will award the prizes on the basis of quality of work in whatever subject the teacher may choose, bearing directly on weather and climate. Owing to the late date at which this circular is issued, work covering only the second half of the school year, 1896–97, will be accepted in the first competition.

The papers submitted should be received in Cambridge by July 10, 1897. Address: Prof. W. M. Davis, Museum, Cambridge, Mass. Express charges or postage should be fully prepaid. If it is desired to have the papers returned full directions should be given for post office or express address; and if return by mail is desired, stamps for postage should be inclosed.

The committee will be glad to give further information, if desired.

W. H. NILES,
Professor of Geology and Geography in the Massachusetts Institute of Technology, and also at Wellesley College.
W. M. DAVIS,
Professor of Geology at Harvard University.
R. DEC. WARD,
Professor of Meteorology at Harvard University.

CAMBRIDGE, MASS., *January*, 1897.

LIQUID AIR.

The students of chemistry are familiar with the fact that a century ago Lavoisier foresaw the novel chemical results that would be realized if ever we should be able to cool and compress gases down to the point of liquefaction, but the realization of his ideas was reserved for the present generation of physicists. Faraday and Thilorier first distinguished themselves by the production of liquid and solid carbonic acid gas, but a later generation, Pictet in Geneva, Cailletet in Paris, Olzeffski and Wroblenski in Cracow, Ramsay and Dewar in London, have reduced many other gases, including oxygen, nitrogen, and, possibly, hydrogen to the liquid condition. Improvements and simplifications in the apparatus have been made from time to time, but it seems to have attained its simplest and most efficient construction in the hands of Dr. Karl Linde, Professor of Applied Thermo-dynamics in the Royal Bavarian Technical High School at Munich. The simple principles of thermo-dynamics which underlie Dr. Linde's apparatus are, in fact, of daily application in the workings of the free atmosphere itself. When any portion of the atmosphere is pushed up to a higher level it cools by expansion, that is to say, the internal molecular energy called heat is drawn upon to do external work or heat is transformed into work and the mass of gas from which the heat is thus withdrawn necessarily cools; vice versa, when air is brought down to a lower level it is compressed by the weight of the additional atmosphere above it and is warmed, that is to say, external work is done upon it, just as when we hammer a piece of lead a portion, or in the case of the air, all the external work is converted into heat.

We are indebted to Mr. O. L. Fassig for an early number of the *Vossische Zeitung* of Berlin, January 12, 1897, containing the following account of a recent public lecture by Prof. Dr. Karl Linde before the Berlin Association of Engineers, Illustrating as it does the results of a special application of processes that go on daily before our eyes in the free atmosphere, these experiments must, therefore, have as much interest for the meteorologist as they have for the physicist. In the early part of this century "the cold of elevation" was often spoken of without any clear conception of the fact that in the process of elevation the air is cooled by the internal work done in expansion; generally it would seem that the air was supposed to cool by contact with the ground or by mixture with other colder air. Physicists knew that gases cooled by expansion, but Espy seems to have been the first who realized the importance to meteorology of both expansion and compression. Probably we are not even yet ready to accept the widest application of the principles of warming by compression, although the fullest range is given to those who invoke the cooling by expansion. In fact, however, whether the air ascends in small masses, as in tornadoes, or in large masses, as in the passage of westerly winds over the Andes and the Rocky Mountains, there must be a corresponding amount of descending air, and this must be warmed by compression. The air that ascends and cools in the equatorial regions, like the air that ascends and cools on the easterly side of an area of low pressure, must have a counterbalancing mass of descending air somewhere within the atmosphere. If in one region the cooling due to expansion is partially counterbalanced by the warming due to the evolution of the latent heat of the moisture that is condensed by the cooling, then in some other region, and to an equivalent extent, the warming of this same air by compression as it subsequently descends must be partially counterbalanced by some cooling process, such as the radiation of heat from the gas, or from the vapor or the dust that it contains. If this were not the case, we should be liable to extremely high temperatures whenever and wherever a mass of air descends. Illustrations of rapid descent and consequently warm weather are to be found not only in the fœhn and dry chinook winds but on the south side of our low areas and, notably, over large portions of the Mississippi Valley and the eastern slope of the Rocky Mountains, which are subject to occasional extremely high temperatures, relatively speaking, without any special increase in the heat from the sun or the clearness of the sky.

But to return to the lecture by Professor Linde, the *Vossische Zeitung* says:

The January meeting, held on the 6th of January under the presidency of Privy Counselor Professor Rietschel, was one of the greatest events in the history of the Berlin Society of Engineers. Prof. Dr. Karl Linde of Munich exhibited his magnificent experiments on the condensation of gases and showed liquid air in such quantities that it was handed around to the audience by the glassful. In order that these experiments might be made, the session was not held in the usual place of meeting, but in the electro-technical lecture room of the Technical High School at Charlottenburg near Berlin, and among the audience which filled up every corner of the large hall were to be seen nearly every person of note among the professional engineers, the teachers of engineering and the higher technical authorities. The lecture began with a dissertation on the physical conditions attending the condensation of gases. At certain pressures every gas has certain "critical" temperatures at which it begins to become fluid. For atmospheric air under a pressure of 39 atmospheres the critical temperature is —140° C.; at ordinary, or one atmosphere, —191° C. Now the the question is how this low temperature is to be produced. One way is, first, to prepare fluid carbonic acid, then with the help of the cold of evaporation of this substance (—50° C.) to prepare acetylene or some other liquid gas whose boiling point is considerably lower than that of the liquid carbonic acid. This method has, however, been abandoned as too laborious and expensive. Much simpler is the method by the compression of the gas and its expansion after cooling; that is to say, on the principle of the ordinary cold air machine, only of a more perfect construction. When a gas is compressed it becomes warm; when released so that it occupies the original space, there occurs a cooling back to the original temperature. If, however, the heated gas be cooled off while it is still compressed and then allowed to expand there will result a cooling to some point below the original temperature and this temperature will, in fact, be lower in proportion to the cooling of the compressed gas. A very ingenious apparatus has now been contrived in which the cooling of the condensed gas is effected by means of its own cooling by expansion. A small metal tube is placed within a larger one; the compressed gas is forced into the small tube. A throttle valve on the end of the small tube allows a diminution of pressure and at the same time the conduction of a part of the expanded and cooled gas backward through the larger tube. The direction of the flow of the gas in the large tube is therefore opposite to that in the small tube so that the cooling takes place in the most perfect manner. By the repetition of this process the second diminution of pressure brings the gas down to the ordinary atmospheric pressure and by a second application of the cooling flow in the opposite direction we attain extraordinary low temperatures and in this way succeed in liquefying the air itself.

A double compressor first compresses the air to 16 and then to 200 atmospheres; vice versa in the cooling tubes the first throttle valve allows a diminution of the pressures to 16 atmospheres and the second to one atmosphere. The liquid air thus obtained, since of course it will not remain liquid under ordinary conditions, but will very rapidly evaporate, is collected and preserved in glass flasks having double walls.

The space between the two walls of the glass flask is exhausted of the air and a few drops of quicksilver are inserted therein. This quicksilver evaporates into the vacuous space and forms a mirror by condensing on the cold inner glass wall. This mirror hinders the radiation of heat while the vacuum hinders the conduction of heat. In this way scarcely a thirtieth part of the heat enters the liquid that would under ordinary circumstances penetrate into the interior of the flask.

It is well known that the air is a mixture of four parts of nitrogen and one part of oxygen and since the nitrogen is liquefied at a temperature about 10° C. lower than that of oxygen, it is apparent that at the beginning of the liquefaction more oxygen than nitrogen passes over into the liquid condition. We are, therefore, dealing not strictly with fluid air, but with a mixture of oxygen and nitrogen that is richer in oxygen than ordinary air. The liquid exhibited to the audience consisted of about one-third nitrogen and two-thirds oxygen. It demonstrated its richness in oxygen visibly by its delicate blue color since oxygen is blue and nitrogen colorless, as, also, by the readiness with which a glowing bit of wood dipped into it flamed and burned, as also, by the increased heat produced in a flame of gas when this vapor was conducted into it; the lecturer showed this heat effect by means of the well-known Drummond lime light. The extreme coldness of the liquid was demonstrated by the formation of fog in the neighboring air, as also by the behavior of the fluid when poured into an enameled dish having the temperature of the room; in this case the fluid circled around until the dish was cooled precisely as in the Leidenfrost experiment when water is dropped into a heated platinum dish. Such extraordinary cold produces burns on human skin similar to those produced by great heat. Therefore, one must handle the cold glass vessels with great care; in the enthusiasm of the experiment the lecturer himself received such a blister, which, therefore, served as a further illustration of the low temperature of the liquid. Mercury and alcohol froze when in contact with the liquid air.

What the lecturer said as to the possibility of the industrial applications of liquid air or liquid oxygen was of importance. Of course the separation of the two portions of the air into one that liquefies easily and one that liquefies with more difficulty suggests the question whether we have not here found a method of cheaply manufacturing oxygen on a large scale. In one hour and with the expenditure of one horse-power, and therefore for one pfennig (one-quarter of a cent) five cubic meters of air can be liquefied. When we reflect that for industrial applications pure oxygen is not necessary, but that a mixture of equal parts of oxygen and nitrogen will suffice, we see at once that here there really is much promise for the future. Industrial chemistry is already paying great attention to this matter; experiments have already been made looking to the application of liquid air to the preparation of chlorine and sulphuric acid. A greater purity of the liquid oxygen is certainly desirable in the transportation of the liquid in "bomben," or shells, corresponding to the transportation of liquid carbonic acid.

THE VALUE OF THE METER AND YARD.

The REVIEW for December, 1896, page 462, gives the value of the yard that is recommended for adoption by the International Bureau; 0.9143992 meter, or 1 meter equals 1.0936143 yard, or 39.370113 inches. It is not recommended that one should adopt 0.91439916 meter, whence would follow, 39.370115 inches. The latter value has been commended to the Editor as the proper result of the work of the International Bureau, but it is best to adhere to the value recommended by that body.

INTERNATIONAL CLOUD OBSERVATIONS AT TORONTO.

In connection with the articles on international cloud observations in the United States, the Editor has received (too late for insertion on a former page), through Prof. R. F. Stupart, Director of the Canadian Meteorological Service, the following special contribution describing the method of observation in use at the Toronto Observatory.

CLOUD OBSERVATIONS AT TORONTO.

By F. L. BLAKE, Astronomical Assistant, Meteorological Observatory (March 5, 1897).

Observations for cloud heights, velocities, and directions were commenced at Toronto on September 21, 1896. Some time had been previously taken up in locating suitable stations and determining the bearing of the base line, its length, the instrumental errors of the instruments, and making telephonic communication. The roof of the School of Practical Science, a little to the east of the Observatory grounds, was chosen as one station and called *A* (all the cloud heights being referred to it), and for the other the roof of St. Andrew's Market, this station being called *B*. These stations are visible from one another and numerous observations of the sun were taken from each to establish the bearing, the resulting adopted direction being S. 15° 23.6′ W. from *A*. The length of the base line was accurately determined by rectangular chaining with a 100-foot steel ribbon chain and ascertained to be 1552.4 meters.

The instruments consist essentially of two ordinary surveyors' theodolites, the telescopes being removed and a long axis made for each and mounted in the Y's of the standards. These axes project some 4 or 5 inches clear of each side of the theodolite, and on one arm is mounted a sighting tube with cross wires at the object end and small adjustable pin hole at the eye end; on the other arm is fixed a camera for the instantaneous taking of cloud photographs; attached to each